March 13, 1862.

Major-General SABINE, President, in the Chair.

The following communication was read:—

"An Account of some Experiments with Eccentric Oblate Bodies and Disks as Projectiles." By R. W. Woollcombe, Esq. Communicated by Prof. Stokes, Sec. R.S. Received March 11, 1862.

It is known now that, especially in the larger calibres, the rifle principle has effected more for shells than for solid shot. A high initial velocity, it appears, cannot be attained with this principle and cylindro-ogival elongation; this slow initial motion is, however, but slowly lost; while in a spherical projectile, such as the 68-pound solid shot, the conditions are of a reverse kind.

The object of this paper is to place before the Royal Society an account of some experiments with models on a design which appears to me likely in large guns to effect, not only an initial velocity greater than that of spherical shot, but a terminal velocity better sustained than that of rifle projectiles.

Fig. 1.
Transverse section of eccentric disk, of actual dimensions.

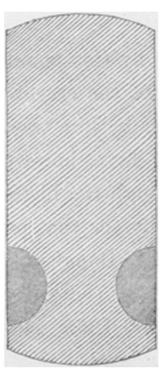
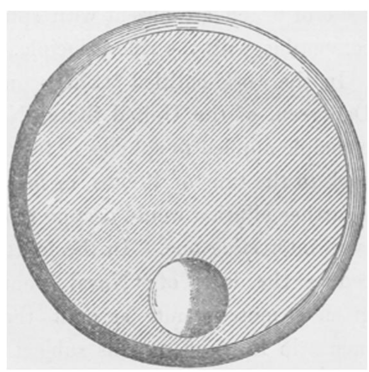


Fig. 2.
Side-view of disk, actual size; eccentric by a shallow and unfilled hole on each side



Average weight of disk in cast iron, 7¾ ozs., wrought iron, 8¼ ozs.

It is proposed to retain the circular periphery of a sphere only in the line of motion, and by cutting away the opposite sides of a sphere in parallel planes, say to half the radius, leave a disk, in that case with a zone of 60° (fig. 1).

I am informed by Professor Stokes, who kindly made the calculation, that such a disk (zone of 60°) is in volume or weight 1·45 times that of a sphere the sectional area of which is equal to the transverse sectional area of the disk. Could such a disk, fired from a gun of similar transverse section, be projected with sufficient cycloidal rotation to maintain it in one plane, assuming it fired in a vertical plane, the conditions appear favourable to dynamical effect at any elevation.

I find, however, that when *con*centric and homogeneous, a disk so fired from such a gun strikes a target, not in the vertical position as fired, but in any position, such as broadside on; and that it is necessary for the desired effect that the centre of the gravity of the disk should be slightly out of its geometrical centre, though not out of the equatorial plane, and placed in a certain position in the gun. I do not propose to employ eccentricity exactly as it has been employed in spheres, that is, to seek to gain range by the eccentricity as such, but chiefly to employ merely enough of it to secure due rotation, so as to make a disk, otherwise useless but at close quarters, a virtually elongated projectile, and dependent further for its effect on the more legitimate and substantial conditions of easily suppressed windage, rotation in aid and not at the expense of translation, facile displacement in the gun, and several other qualities, some of which are absent with spherical projectiles, and others incompatible with the rifle principle.

In the work entitled "Shells and Shell-guns*," by Commander Dahlgren, of the United States Navy, the history of the eccentric principle applied to spheres is treated at length, and by him traced back to the time of Robins, or for about 100 years; here, however, a further allusion would occupy too much space, though the history is an interesting one. In the fourth edition especially (or that preceding the last) of 'Naval Gunnery,' Sir Howard Douglas has given a more minute account than has Dahlgren of the experiments in England on this subject in 1850, 1851, and 1852, which were instituted at the suggestion of Sir Howard Douglas.

It is stated by him that it was by the experiments of General Paixhans at Metz, in 1841 and 1842, the fact was first established that the deviations of eccentric spherical projectiles could be made to occur at will, either in a lateral or longitudinal direction,—laterally,

* London, Trübner and Co., Paternoster Row, 1857.

by placing the shot with its centre of gravity to either side of the geometrical centre, to which side the deviation then occurred, and longitudinally, by placing the centre of gravity above or below; in the former position the range was increased, and when "below," the range was diminished relatively to the range of a concentric sphere of like dimensions, and of a weight approximately equal, but not necessarily exactly so. In these latter positions (*i. e.* in a vertical plane) there was found by General Paixhans to be also a relatively reduced amount of lateral deviation in comparison with that of common spherical projectiles; in shot the difference was as 8 compared to 13, and in shells as 2 to 16*. In the English experiments, however, of 1850, 1851, and 1852 it does not appear, from the published results, that lateral deviation was thus reduced, excepting at some or the longest ranges†. Of these the greatest was with a 68-pounder of 95 cwt., charge 12 lbs., elevation 24°, the shot being hollow and eccentric (but its weight and mode of eccentricity not mentioned); this shot ranged to 6500 yards‡, while the greatest range at the Deal experiments of A.D. 1839 with a 56-pounder gun and solid shot, 16 lbs. charge instead of 12 lbs., and 32° elevation instead of 24° only, was 5720 yards§.

The conclusions arrived at in England, France, and America from the results of experiment with eccentric spherical projectiles appear to be very similar, as regards the general inutility of the eccentric principle for any but certain exceptional occasions in warfare, such as the bombardment of a distant but very extended area. It has, however, been used in spherical projectiles in the Prussian field artillery‖; and Dahlgren states that when the centre of gravity, of a shell that has no more eccentricity than about $\frac{1}{54}$ of its weight added about the interior of the fuse-hole, is placed in the axis of the bore¶, or rather parallel thereto as regards the geometrical centre, the lateral deviations are nearly annulled**, and the longitudinal

* Naval Gunnery, ed. 4. p. 152. † Ib. p. 166. ‡ Ib. p. 168.

§ These two ranges are the greatest of any recorded in the 'Naval Gunnery,' with respectively eccentric and concentric spheres.

‖ Vide Taubert on the 'Use of Field Artillery,' translated from the German by Lieutenant Maxwell. London, J. Weale.

¶ Dahlgren says that such use of the eccentric principle is made in the U.S. Navy for shells.

** Dahlgren, p. 94.

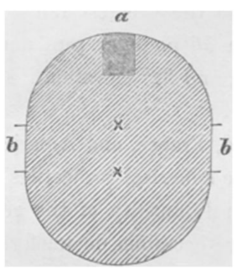
variations are much less than those of an ordinary shell not made purposely eccentric.

He states that, *con*centricity * being unattainable in shells, it is needless to inquire whether that or eccentricity is to be preferred, the real question being how best to deal with the eccentricity of all shells.

Of solid shot, Sir Howard Douglas remarks that not more than one out of a hundred, when floated in mercury, remained indifferent to the position in which they were placed in the mercury; while it was made manifest, by the experiment with eccentricity, that that quality was of all others by far the most fertile cause of deviation.

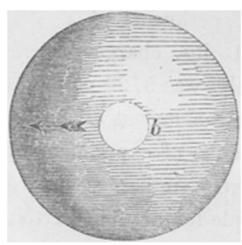
I now proceed to my own experiments †. My first idea (in 1854) was to employ, with the least amount of eccentricity sufficient to

Fig. 3.
Actual size of bore and transverse section of spherical shot (allowing for windage).



a, Plug of wood.
b b, Plane surfaces.

Fig. 4.
Side-view of spheroid.



effect cycloidal rotation, a form of projectile and section of bore of gun of very little oblateness. I procured two model mortars; one

* Dahlgren, p. 92.

† While endeavouring to rifle a small model mortar, and holding it obliquely, I was struck by the elliptical form of the muzzle presented by thus inclining the circular bore to one side; and happening at the time to be thinking of some of the details of the experiments with eccentrical spherical projectiles in the 'Naval Gunnery,' it occurred to me that if a gun was elliptically bored, but the bore straight and not helical, the long axis being in a plane perpendicular to the common axis of the trunnions, and the shot an oblate spherical *ec*centric (as already described), and properly placed in the bore, such would be an advantageous application of the eccentric principle, as the shot would rotate *ab initio* about its natural or shortest diameter, and the direction of such axis and of the plane of rotation could not alter within the gun, or be likely to alter through the air.

was bored at first to an ellipticity differing but little from a circle, not, however, a true ellipse, but two semicircular arcs, on centres a little separated, connected by straight lines at the periphery; and corresponding projectiles were made similarly differing from the true form generated by an ellipse about its minor axis. The difference, however, between the long and short axis of the figure of the shot was insufficient to obviate its getting crosswise in the bore, by means of the necessary windage to allow of free rolling in the bore.

The mortar was then re-bored to its present dimensions, by the kind aid, in lending instruments, of Mr. George Hoffman of Margate. Fig. 3 represents a section of the bore in its present state.

On this very small scale nothing, however, of any consequence could be ascertained in either force or accuracy, though a singular result appeared as to effect of relative position of centre of gravity; for in both models the longest ranges were afforded by a position of the centre of gravity which was the reverse of that giving the longest ranges in large guns.

Ranges.	Large guns.	Models.
Longest............	Above............	Below.
Second	Behind	Behind.
Third	In front	In front.
Shortest	Below............	Above.

The reason seems to me, as regards the models, to be, that the powder has more time for complete ignition in such very short tubes when the shot is in stable equilibrium than when in the reverse position. The mortars were used as guns at low angles.

Fig. 5.
Side-view of disk of 5 ozs.
Actual size.

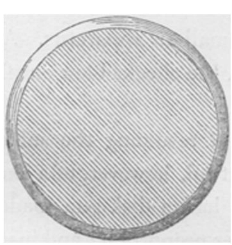
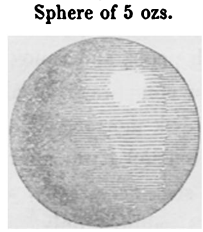


Fig. 6.
Section of
disk.

Fig. 7.
Sphere of 5 ozs.



I adapted one of them to project disks (figs. 5, 6) which were of about the same weight (5 ounces) as the spheres (fig. 7) for the other mortar.

I also made the mortars of the same length, namely small. They were fired from a moveable wooden platform, but each from the same bed or block of wood, which slid in a groove in the platform; the bed admitted of their being fired at the horizontal and at low elevations.

Recoil could be marked; the usual charge was 3 drachms of fine canister powder; the disk caused more recoil than the spherical shot, as in the former windage could be more effectually suppressed. Centre of gravity *below* in both gave more recoil than centre of gravity *above*. The eccentric disks and spheres were *usually* fired with centre of gravity *below*. The disk ranged to first graze about $\frac{1}{3}$, and at the extreme range about $\frac{3}{5}$ further than the range of the eccentric spheres; that is, as 4 to 3 to first graze, and at the extreme range (after grazing) as about 8 to 5. But there can be little doubt, from the light thrown on this point by my later experiments, that no sufficient rotation of a cycloidal kind could have been imparted to the disks from the mortar, the centre of gravity being below, but only from their striking the sand, as if the disk were bowled from the hand; the disks ricochetted to between 600 and 700 yards up to 3° elevation, above which angle there was no good ricochet. The mortars were about 10 or 12 inches above the level of the sand.

When a disk touched a rough place, though much oscillation was set up (as known by the noise it produced), this lasted only to the next one or two grazes; for at the end of the range, where the disk rolled before stopping, and the sand happened to be soft and dry, the track was continuous like that of a wheel, and in a line that was very straight.

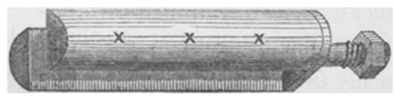
Some experiments with these mortars and disks were shown by me at Shoeburyness in 1855; but the ground there consists of mud with pools, and is not level enough for so small an apparatus. After a few comparative trials of the two mortars, the cheeks blew out from the disk mortar.

In 1859 I was afforded an opportunity of resuming the subject; but still, necessarily, with a *model* only; instead, however, of a length of 3 calibres only, as in the mortars, I had a disk-gun made of between 10 and 11 calibres, or about howitzer proportion; and instead of, as previously, a weight of disk of 5 ounces, the weight was about 8 ounces. Length of bore of gun 20 inches, long diameter of

bore $1\frac{7}{8}$ inch, and of disk nearly the same, and transverse diameter $\frac{3}{4}$ inch (see figs. 1, 2). Thus the disk was virtually a slice from a sphere, and across a zone of about 48° or 49°. Its long diameter was about $2\frac{1}{2}$ times the short diameter.

The gun was first bored to a cylinder, and the bore was then reduced to the proper shape by the insertion of two cheek pieces. I had difficulty in securing the cheeks of the gun, and found, after two failures with side-bolt fastenings, that it was requisite to secure the cheeks in the line of their length by attaching them to the head of a bolt (like the prongs of a tuning-fork to its handle), which passed through the breech end of the gun in the line of its axis, and was secured on the outside on its projecting screw end by a nut (see fig. 8).

Fig. 8.—Perspective view of cheeks.



The crosses show places for side-bolts to keep cheeks close to sides of cylindrical bore.

The gun was made so that the longer axis of the bore was, throughout the gun, perpendicular to the common axis of the trunnions. The gun weighed about 130 lbs. It was simply a cylindrical block with trunnions; I had, *in it*, to learn how to effectually secure the cheeks, and therefore had the gun made of a thickness otherwise unnecessary.

The first disks made were cast with the mould in a *horizontal* position; and several such disks were fired; but scarcely one of them had the centre of gravity in the equatorial plane; and I found that a disk that would not roll tolerably straight (as on a level table), had corresponding lateral deviation in the air when fired. Other disks were then cast with the mould in a *vertical* position, and these were much more symmetrical in respect of the sides.

The eccentricity was given at first by a hole through the disk, plugged with gutta percha, or with an alloy of lead and tin; experience, however, showed that plugs of any kind, though riveted, were often blown out, and could only be secured by being *screwed* in; and eventually I found no way better than to employ symmetrical shallow cavities* *un*filled, on each side of the disk, at about half the radius from the centre. The least amount of metal

* I am indebted to Mr. Braid, late R.A., of the Dep. Military Prison, Devonport, for his kindness in making these cavities in the disks by a lathe.

abstracted, which I found would effect rotation, was $\frac{1}{120}$ only of the disk's weight, and was removed from the sharp edge at the sides of the zone by filing at four points. Rotation was effected also in a homogeneous disk, and without any cavity, by making it slightly oval in periphery—in fact, as if it were a middle slice from a *very slightly* ovoid or egg-shaped body, instead of from a spherical one, the larger end or heaviest part being put uppermost in the bore. Excepting one other form, better described presently, these were all the forms I experimented with.

The gun being too small to effectually destroy a sabot, I commonly used a horse-shoe electro-magnet sliding in one end of a flat wooden rod of similar section to the bore of gun, with which to place the shot in any desired position. Having previously marked, by a spot of chalk, the face of the shot to be seen in front when in its place, I placed the shot as desired in the bore, and then by throwing in light with a mirror, I saw that the position was that wanted. Sometimes, if the shot turned in entering, it could not be again withdrawn but by firing; and thus such cases conveyed no meaning, unless the spot of chalk was not altogether out of sight, in which case the position and result were recorded.

In September 1859, by the kind permission of Captain Jerningham, R.N., in command, the gun was placed on board the 'Cambridge,' the gunnery ship at Devonport.

The first experiment was to ascertain the ranges due to centre of gravity above and below; and this would also show whether rotation occurred in one or the other position, or in both. Four disks were selected of within a few grains' weight of one another, average weight $7\frac{3}{4}$ ounces; three of the disks were to illustrate respectively *con*centricity, and the two opposite positions of centre of gravity "above" and "below." The charge was $1\frac{1}{2}$ ounce, and the elevation 5° in each case; the powder was that known as "Lawrence's No. 4, large-grain," and is a powder of great strength.

The *con*centric disk dropped at 550 yards; the *ec*centric with centre of gravity "below," at 500 yards; the *ec*centric with centre of gravity "above," at 1000 yards. The two first-named disks made much noise in passing through the air; the long-ranging disk, fired with centre of gravity *above*, made but little such noise.

The other eccentric disk was then fired with 2 ounces instead of the

$1\frac{1}{2}$-ounce charge, and at 10° instead of 5°, the centre of gravity being above as before. This shot was neither seen to drop in the water nor heard to make much noise. There was about 2000 yards of water then in the creek; and as the water was smooth, and many practised eyes were looking out, it was thought likely to have passed all the water and fallen on the mud. This view was much confirmed by three similar eccentric disks being similarly fired a few days after, *i. e.* with 2 ounces of powder and 10° elevation, and centre of gravity above. On this occasion Capt. Jerningham kindly sent out a boat near the 1500-yard range, and men were stationed about the ship to observe. The water was smooth, and, as before, there was about 2000 yards of it in the creek. Not one, however, of these three disks was seen to drop by any one, nor were they heard from the boat, so that there could be little doubt that rotation was established. A fourth eccentric disk was entered, but stuck in the bore, and was pushed down in a position unknown. This was also fired at 10°, and with the same charge as the preceding, and it was seen to drop at about 1000 yards, and was believed to have had no regular rotation. On Oct. 5th, 1859, the gun being on the lower deck, about 11 feet above the water, two eccentric disks were fired with centre of gravity above, the gun being laid horizontally, or what is called point-blank; charge as before, 2 ounces. The first graze of both of these shot was between 600 and 700 yards; and there could be no doubt of the range being due chiefly to velocity, and not to vertical deviation, the graze of the shot succeeding so immediately the discharge from the height of the gun from the water having been about 11 feet, and the gun horizontal. The range, if not due to vertical deviation, must have been due to a velocity of more than 2000 feet per second. In these early experiments with the model disk-gun, I had not the advantage (as at present) of having previously fired at timber, so as to have learned unmistakeably the effect on the position (as in striking in a vertical or oblique plane) of different amounts of lateral (or undesired) eccentricity; also I knew nothing of the injurious effect of sabots on the shot's rotation when the sabots were too substantial; consequently the majority of these earlier experiments were most uncertain, and could not be repeated at will.

I have, however, since, by firing at timber, learned the conditions which secure certain results; and these I will briefly state. Excepting when the centre of gravity is "above," or within a few degrees of

such position, a disk strikes a target not in a vertical plane as fired; but when the centre of gravity is "above," when the disk is free to roll and not merely slide in the bore when the sabot, if any, is very light and destructible, as of card, when there is a sufficient charge of powder, and the disk is tolerably symmetrical laterally, and sufficiently eccentric longitudinally (but which eccentricity need not be an amount that causes a dip of more than 1° when the disk is floated in mercury), then the disk, if fired in a vertical plane, is certain to strike a target in that position up to the distances at which I have yet had the opportunity of trying it; and though such distance (from the land experiments here having been of necessity in a quarry *) has been only from twenty to thirty yards, yet, *as in the other* positions of the centre of gravity the disk turns over irregularly *within such distance*, it may be assumed that a rotation in a vertical plane is set up in the one position referred to, viz. "above," and in no other position of the centre of gravity. To this conclusion all these experiments appear to tend. It may by some be questioned whether this rotation is *as* a wheel, or the reverse way, by the advancement of the lower part of the shot. These experiments do not appear to support the conclusions of M. Magnus† (which have been so very widely adopted, as by Sir Howard Douglas in his fourth and subsequent edition), viz. that rotation occurs in both positions of "above" and "below," but in the latter only is *as* a wheel; while previously, and as expressed in his third edition, Sir H. Douglas entertained the opinion that the rotation was in that direction, or by the advancement of the upper hemisphere, when the centre of gravity was above. It is probable that rotation in a disk, in *either* direction, would keep its plane vertical when the projection had been in a vertical plane; so that if it strikes upright only when fired with the centre of gravity in one position (as when "above"), it seems a fair conclusion that with the other positions of the centre of gravity there can be no rotation imparted.

This I had reason to suspect, as regards the position of the centre of gravity "below," long before I had an opportunity of proving it with the disk-gun; for in 1854, the model-mortar experiments referred to

* Capt. Bent, R.A., of the Royal Laboratory, St. Budeaux, near Devonport, was so kind as to afford the ground for these land experiments, which otherwise I should have been unable to carry out.

† M. Magnus's Paper on Deviation of Projectiles in 'Taylor's Scientific Memoirs,' Nat. Phil. Part III. for May 1853.

appeared to indicate that such was probably the case, by demonstrating that not only were the vertical deviations from such models the reverse of those in large guns, while the lateral deviations were the same, but that it followed from this there must be a length and calibre from which, while the lateral deviations still remained constant, the range would be the same whether the centre of gravity of an eccentric sphere were put "above" or "below." What, then, becomes of the theory that the lateral and vertical deviations are due to the same proximate cause, *i. e.* eccentric rotation through the air, and that it is *by* the air, as assumed by M. Magnus, that both these deviations occur? The later disk experiments, *i. e.* from the gun, show that in three out of the four positions of the centre of gravity in one plane (a vertical plane) there is no decided rotation in such plane, or indeed regular rotation in any plane; yet these three positions in spheres all give different ranges.

Do these spheres rotate? or can they in such case rotate in a vertical plane with velocity enough to cause a vertical deviation, assuming that the mean length of a range admits of being increased in this manner, in opposition to gravitation?

Perhaps the approximate causes may be looked for (of the two kinds of deviation), the one more *within*, and the other chiefly *outside* the gun.

As regards the longer ranges due to centre of gravity "above," may not such increase be due to the fact of the nearer coincidence of that important point with the axis of the bore? In fact, may not the vertical variations in range be chiefly due to causes of a more directly dynamical nature than has been generally thought? while, respecting the lateral, M. Magnus's views, founded on his experiments with rotating bodies, appear not only incontrovertible of themselves, but the identity of such deviations in models with those of large guns offers no new fact on which exception could be taken or any new question raised, which cannot be said of longitudinal deviations.

To find whether a disk prevented from rotating in the bore, but still delivered at the muzzle with centre of gravity "above," would rotate in, and in such case by, the air, I made two disks (with a straight edge above and below), the disks being very eccentric by a transverse hole through the lower part.

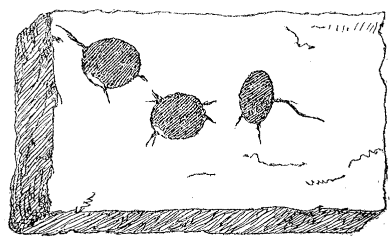
They both struck irregularly in any position, as seen by the wood of the target, which shows also the form of the disks.

I found that a homogeneous solid disk, formed slightly oval below, would strike as fired (in a vertical plane) when the centre of gravity was "above."

There are three ways in which, as I have found, disks may pass through the air (as seen by the target, and shown in figs. 9, 10, 11).

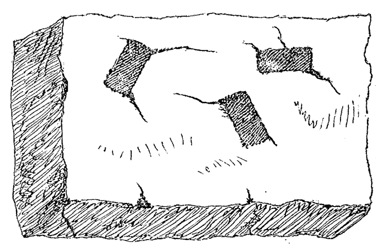
1st. *Con*centricity, or *Ec*-centricity, but with centre of gravity not "above," causes a disk to strike in any irregular position (fig. 9).

Fig. 9.



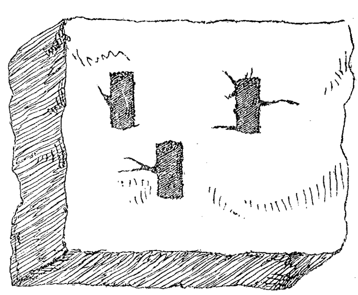
2ndly. When the centre of gravity is "above," but there is something within the bore to hamper but not arrest the rotation of the disk in the bore, such as too thick a sabot, or great fouling and insufficient windage, the disk strikes with the edge, but not upright as fired (fig. 10).

Fig. 10.



3rdly. Centre of gravity "above," with the attending conditions which have been before mentioned, gives a result as previously described and shown in fig. 11.

Fig. 11.



The difficulty of destroying "sabots" is much greater in models than large guns.

The penetration of disks when striking with the edge is great; with a 2-oz. charge, at twenty-five yards, the penetration has commonly been through three 4-inch planks of elm; and with half an ounce more powder and a wrought-iron disk, through three 6-inch beams of elm, the latter with the grain of the plank parallel to the plane of the disk, the former with it usually transverse. The difference of direction in grain of wood causes in such experiments about 2 inches difference in penetration.

I beg, finally, to sum up briefly the conclusions which appear to me to be deducible from these experiments.

1st. That the experiments with the model mortar, by giving the longest range and the shortest that are due to certain positions of the centre of gravity in a vertical plane in positions the reverse of those obtaining in large guns, while the other positions remain the same, as to their effect on the range, as in large guns, appear to render admissible the view that the causes of lateral and vertical deviations, which have hitherto mostly been assumed to be similar, may not be so.

2ndly. That from the above experiment it also results that there must be *a length* and calibre in which the range will be the same, whether the centre of gravity of an eccentric spherical projectile be placed above or below, while in the same gun all the other deviations due to the other positions will be similar to those obtaining in both large guns and small models.

3rdly. It appears (at least with the dimensions of gun and projectile here experimented with) that there is no decided rotation in any of the four positions in a vertical plane, excepting that of centre of gravity "above" the geometrical centre ; and it may perhaps be fairly assumed that in the positions in which disks do not rotate, spheres (at all events, of like dimensions) cannot.

4thly. That if the results of these experiments with the model disk-gun may be viewed as indicative of similar results from large guns, then the above-mentioned phenomenon of rotation *in one position only* renders doubtful the previous conclusions on the direction of rotation, which have been based on a view of the rotation not being thus limited to one position.

5thly. It appears that to rotate outside the gun, it is requisite that the disk (and probably sphere also) must be free to rotate within it.

6thly. That rotation may be imparted sufficient to be permanent on one axis, but not in one plane—a matter of no consequence at close quarters; while, by certain means, rotation may approximately be secured in one plane when the projection has been in a vertical plane ; this has been seen at least up to thirty yards at a target, and longer distances not yet tried at a target; but much within the above distance the other phenomena are seen to occur ; and it may be assumed that if a disk will keep upright through several inches

of solid timber, it will also keep upright through the air, except in much wind, against the effect of which, however, the disk may probably be preserved by inclining the axis of the gun.

7thly and lastly. The before-mentioned results show that a disk-gun may in certain respects be viewed as a common gun, and in other respects as a gun for throwing an elongated projectile. The former characteristics, as of circular periphery in line of motion, ensure high initial velocity and small strain on the gun; and the latter, or virtual elongation, ensures the preservation of such velocity; for it is seen that the requirement of the tangent to the trajectory, so desirable respecting the proper axis of rotation of a rifle projectile, does not obtain in the disk; and it is also seen that while the rifle projectile can strike effectively but in the prolongation of one of its axes, and that becomes impracticable as elevation increases, the disk has no such limitation, and is not dependent on any one angle of elevation for preserving inviolate the conditions for which elongation is given to any projectile*.

* On March 20, in the week following that in which the above was read at the Royal Society, four disks were fired at Shoeburyness, in the presence of Col. Taylor, R.A., Commandant and Superintendent, and other officers. The weather was so wet, the tide also not admitting of the gun being loaded early in the day, that four disks only were fired at a target, first of oak, 9 inches thick, and afterwards with about 4 inches of deal behind it; gun twenty-five yards from target.

Experiment of March 20, 1862.

Powder.	Disk eccentric by between $\frac{1}{50}$ and $\frac{1}{60}$ abs. at $\frac{1}{2}$ Radius.	Position of centre of Gravity.	Remarks.
Ounces. $2\frac{1}{4}$	Between $7\frac{3}{4}$ and 8 ounces.	Behind, in axis of bore.	Hit broadside on, and went deep into, but not through the oak; no splintering or appearance on the far side of the oak.
$2\frac{1}{4}$	Ditto.	Above.	Passed through the oak into the sea. Hit vertically as fired.
$2\frac{1}{4}$	Ditto.	Behind, in axis of bore.	Hit vertically, and passed into the sea, through the oak and the deal backing (oak 9 inches, deal 4 inches).
$2\frac{1}{4}$	Ditto.	Above.	Hit vertically; splintered the oak on far side, but did not go through it. This I stated was a "low" shot (in windage), before firing.